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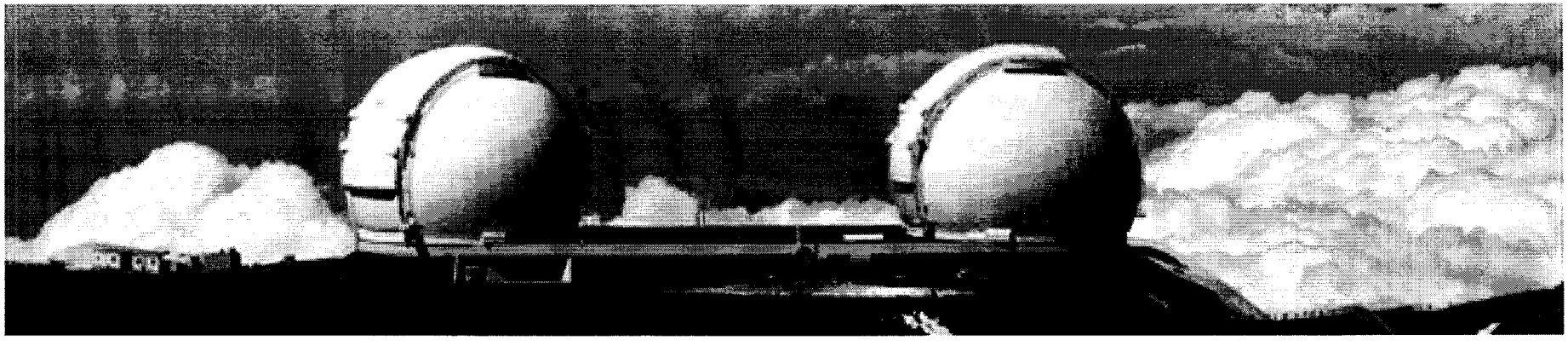
Keck Interferometer Update



Mark Colavita, *Jet Propulsion Laboratory*
Peter Wizinowich, *W. M. Keck Observatory*

Interferometry in Optical Astronomy II
8/22/2002

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The real author list

- **At JPL:** A. Booth, M. Colavita, S. Crawford, M. Creech-Eakman, G. Eychaner, G. Hardy, E. Hovland, R. Johnson, J. Kelley, K. Ko, R. Ligon, B. Mennesson, J. Moore, A. Niessner, D. Palmer, L. Reder, G. Serabyn, M. Shao, R. Smythe, M. Swain, A. Tumminello, G. van Belle, G. Vasisht
- **At Keck Observatory:** S. Acton, R. Boutell, J. Beletic, J. Bell, F. Chaffee, D. Chan, J. Chock, R. Cohen, J. Gathright, M. Hess, M. Hrynevych, R. Kendrick, P. Kurpis, D. Le Mignant, H. Lewis, C. Nance, C. Neyman, A. Rudeen, T. Saloga, P. Stomski, K. Summers. K. Tsubota, J. Vause, P. Wizinowich
- **At the Interferometry Science Center:** R. Akeson, A. Boden, C. Felizardo, J. Herstein, C. Koresko, A. Sargent

See: A. Sargent, "Interferometry Science Center (ISC)," 4838-19

- **Keck Interferometer is funded by NASA as part of its Origins program, and is a joint development of these three organizations**

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Outline

- Instrument status
- First fringes
- Current activities

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Keck Interferometer modes

- High sensitivity fringe visibility (V^2) measurements
  - Combines the AO-corrected beams
  - V^2 measurements in the near-IR
- Infrared nulling at 10 um
  - Nulling beam combiner to suppress central star
  - Measure zodiacal dust around nearby stars
- Differential-phase interferometry
  - Multi-color fringe measurements
  - Detect the fringe shift caused by hot companions to nearby stars

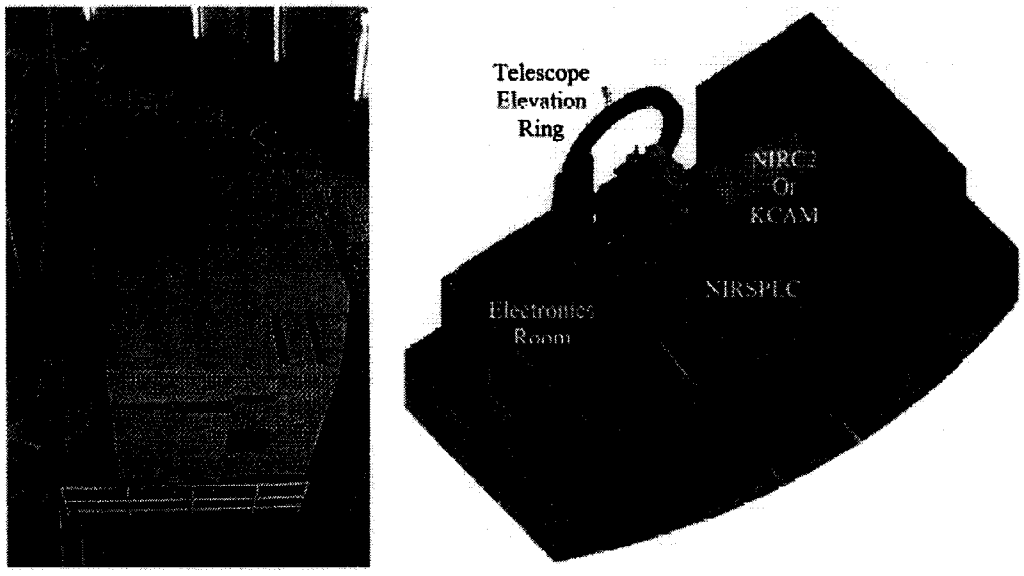
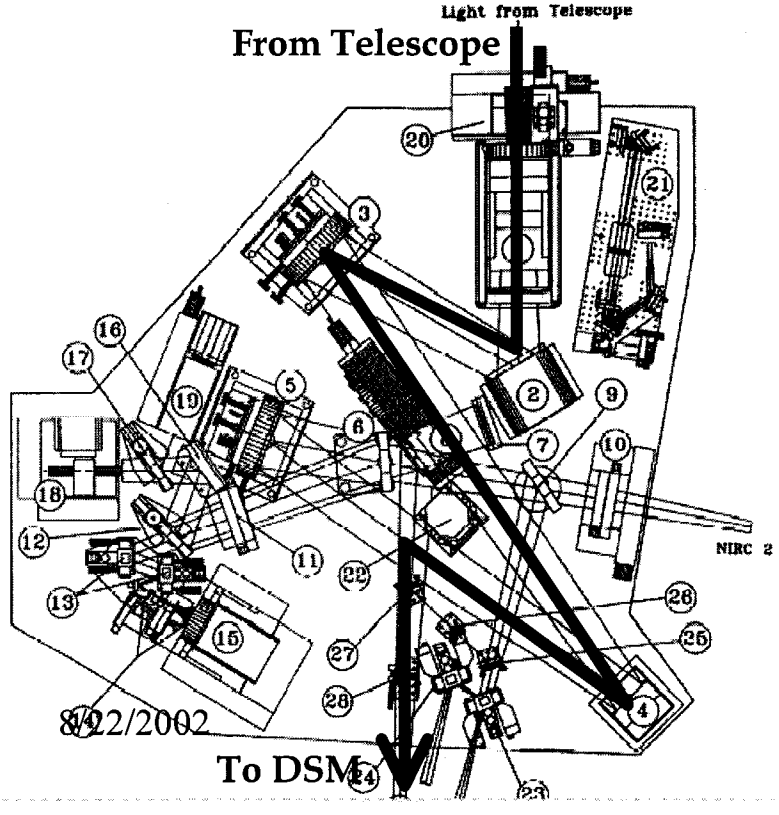


Figure 1. Left: The AO enclosure on the left Nasmyth platform of the Keck II telescope. Right: A schematic view of the AO enclosure with its roof removed.



Telescope & AO

- Extract beam in collimated space on AO bench after deformable mirror
- 9 m inscribed circle on Keck primary maps to 112 mm collimated beam

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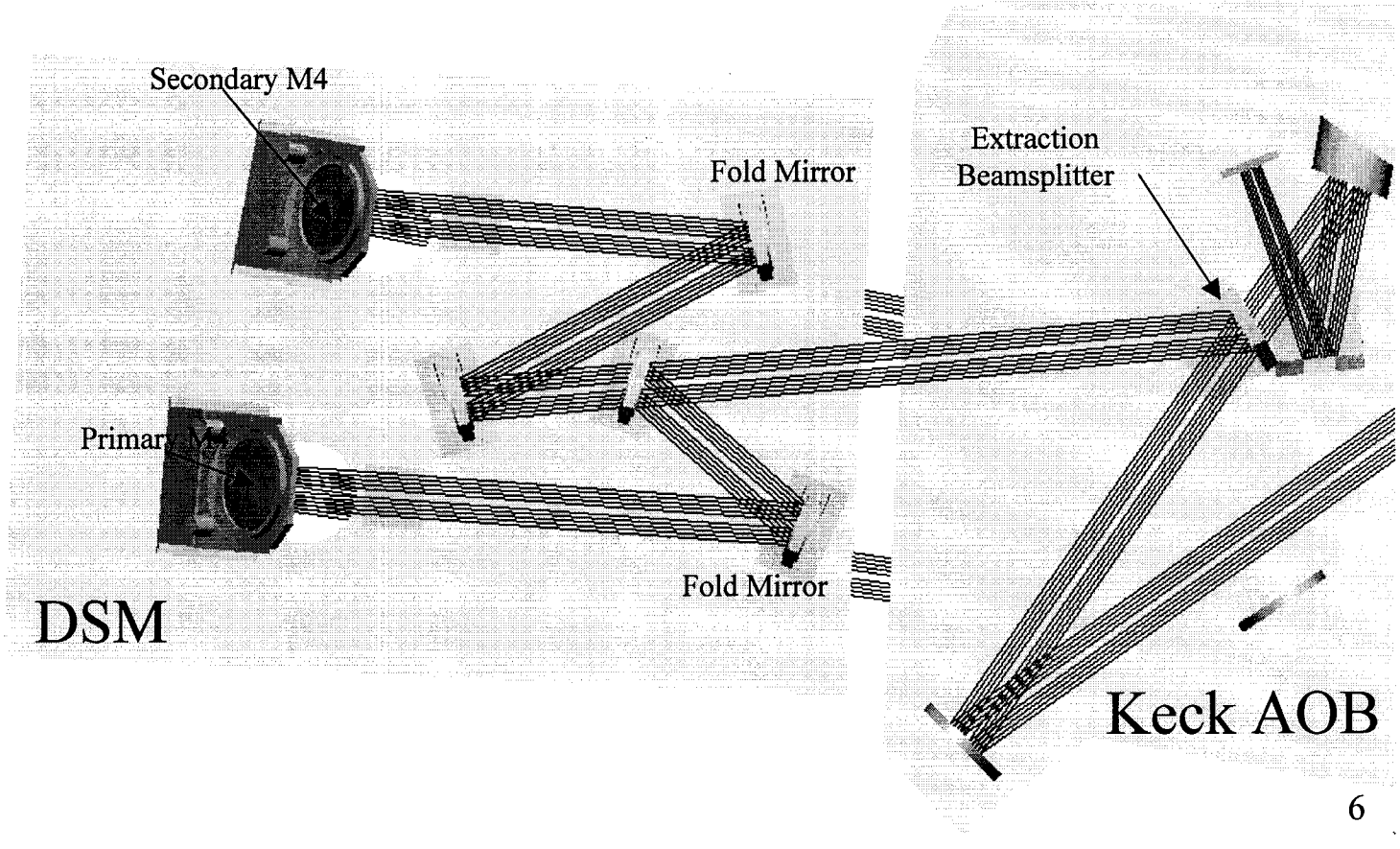
Dual star module

- Slides in adjacent to AO system like other Nasmyth instruments
- Sends collimated beam into coude beam train



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Beam transport

- Coude train relays light to base of telescope
- Transport optics relay light through basement
  - Mounts include targets and actuators for remote alignment

See: G.T. van Belle et al., "Keck Interferometer autoaligner," 4838-50

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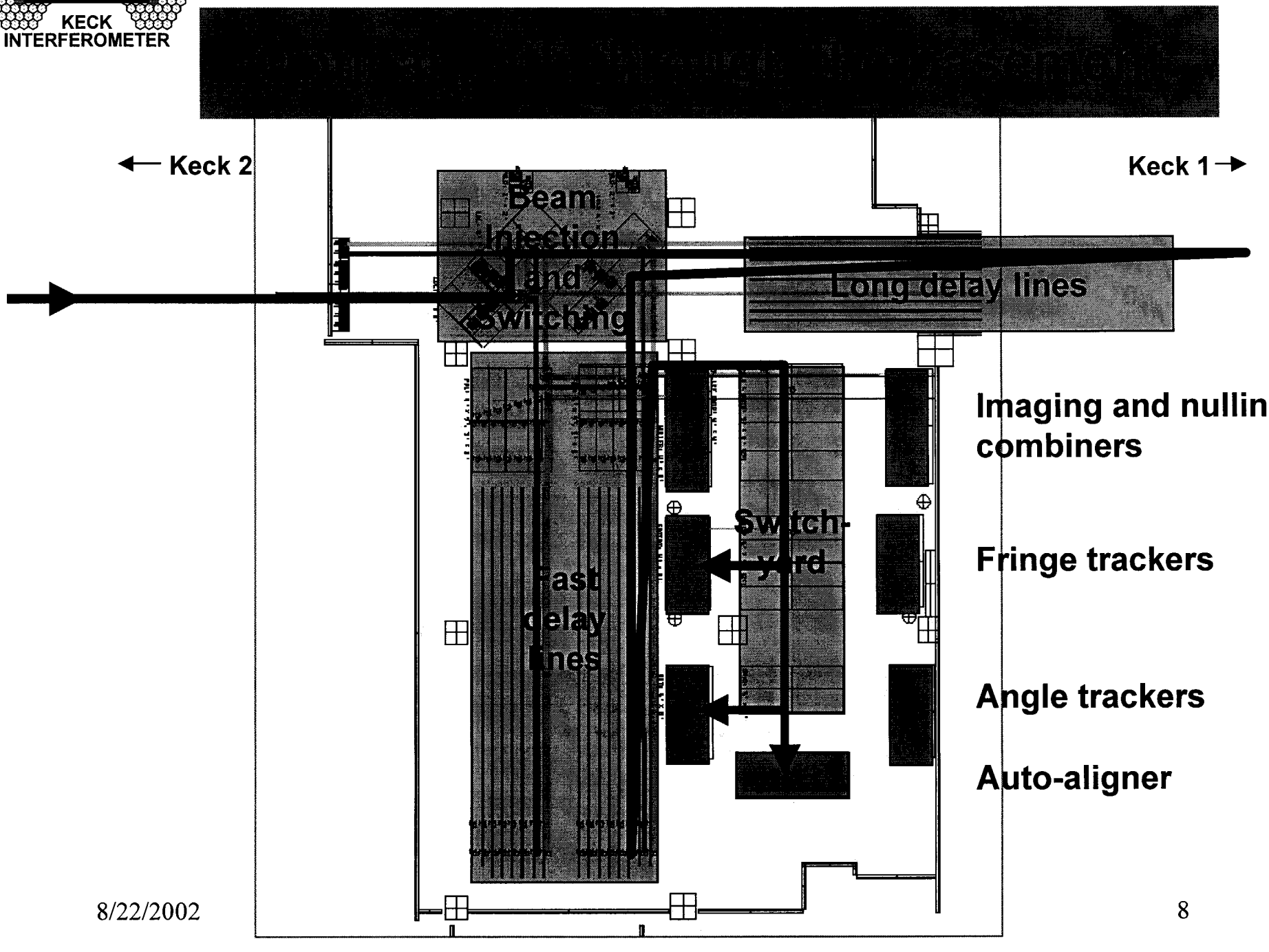

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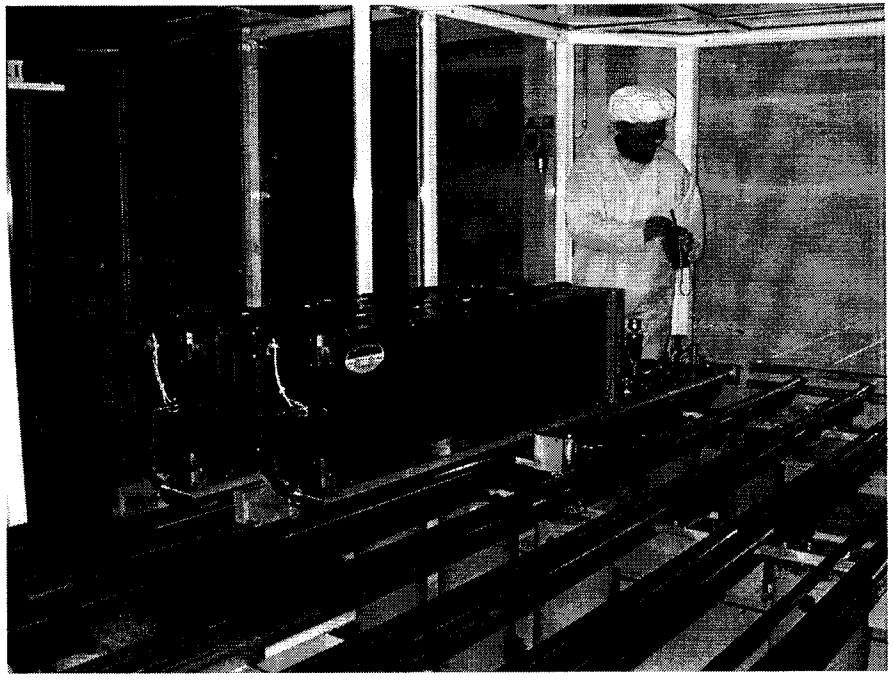
Long delay lines

- Installed in coude tunnel
- Provides coarse delay positioning (static during observation)
- Double-height mirror accommodates two beams for phase referencing

Fast delay lines

- 4-stage cat's-eye design
- Fiber-fed laser metrology
- Delay range +/- 15m
- High speed position and rate commanding

Metrology
launchers



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FATCAT (Fringe tracker)

- Free-space Michelson beam combination at H and K bands
- HAWAII array camera fed by single-mode fluoride fibers
- White-light and spectrometer channels; frame rates of 100-1000 Hz
- Fringe tracking with coherent fringe demodulation, closed-loop to delay line

See: G. Vasisht et al. "Keck Interferometer fringe tracker," 4838-149

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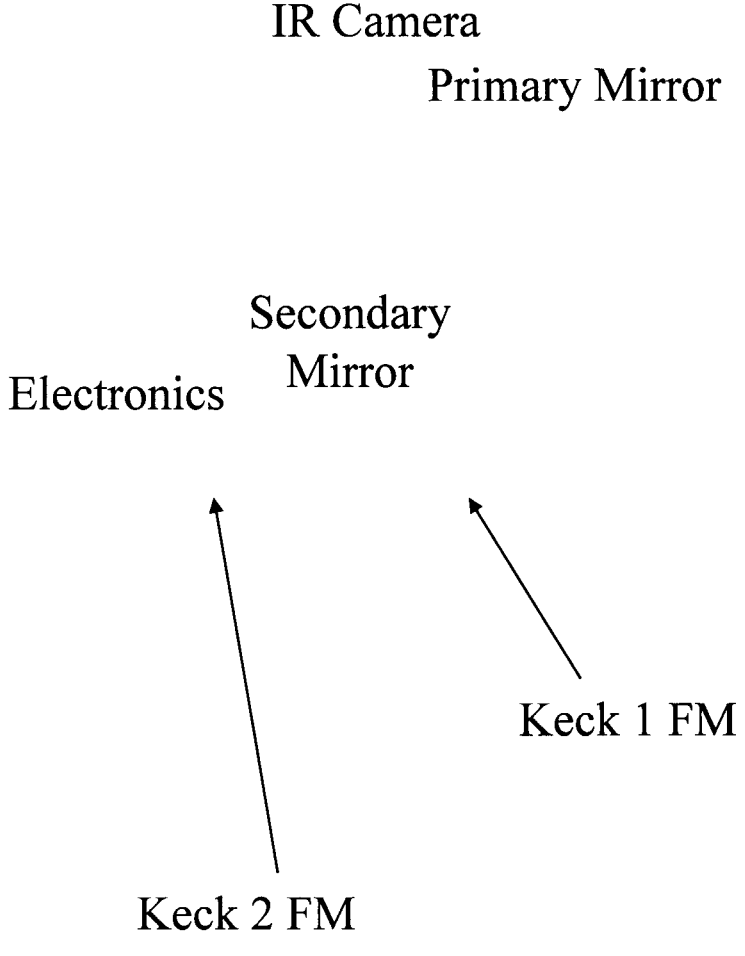
Angle tracker



- H and J band angle tracking
- DCR corrector for good sky coverage
- Images from two Kecks multiplexed onto one quadrant of HAWAII array
- 100 Hz readout
- High-speed updates to local tip/tilt mirror
- Low-speed off-loads to AO system

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Interferometer control system

- VME / VxWorks / PowerPCs
  - High-rate
    - » RTC Toolkit
  - Medium rate
    - » EPICS/KTL
- Unix
  - GUIs
    - » Java, Tcl/Tk
  - Other tools
    - » Configuration, archive, sequencing, planning

See: A.J. Booth et al. "Overview of the control system for the Keck interferometer," 4848-12
T. Lockhart, "RTC: a distributed real-time control system toolkit," 4848-21
L.J. Reder et al., "Using scripting languages in optical interferometry," 4848-32

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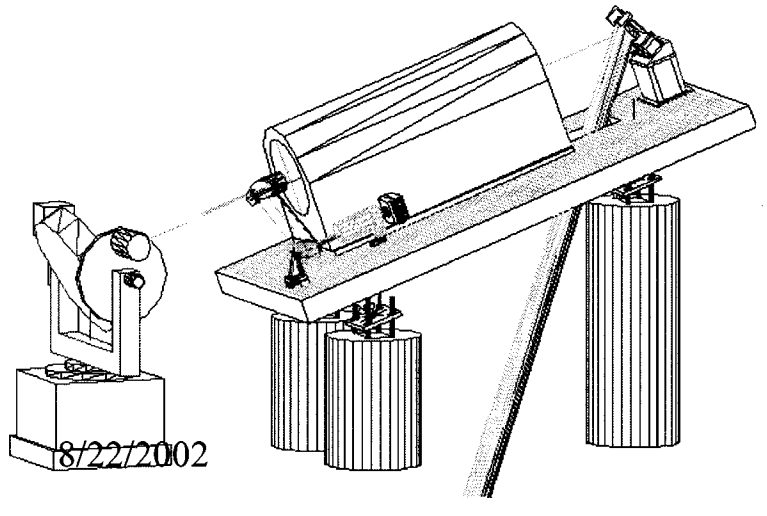
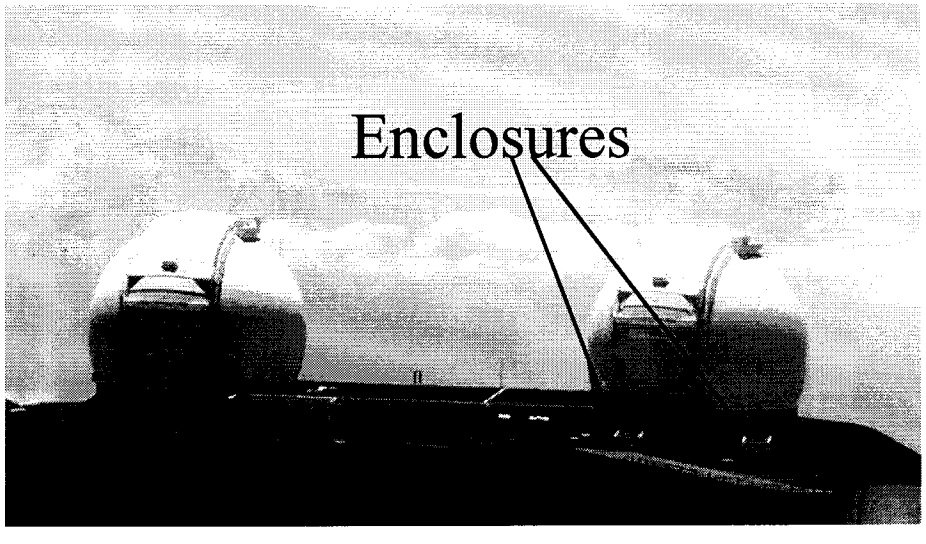
First siderostat fringes

- Initial fringes using the siderostats were obtained on Feb. 22, 2001
  - Checked out hardware to be used with Kecks on next run
- Instrument configuration
  - Two 50-cm siderostats feeding fixed 40 cm telescopes (essentially the same as the PTI front-end optics)
  - Angle tracking at H band controlling fast steering mirrors behind telescopes
  - 10 cm compressed beam routed to beam combining lab
  - Remaining configuration like for Kecks





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First Keck-Keck fringes

- March engineering run: 3 1/2-nights on the two Kecks March 12-14, 2001
- Instrument configuration
  - Two 10 m Kecks feeding interferometer via coude optics
  - Natural guide star adaptive optics running on both telescopes using R and I light
  - Slow guiding corrections to AO system from interferometer angle tracker at H band
  - Fringe detection at K band using interferometer fringe camera
    - » Synchronous demodulation (a.k.a. fringe scanning) with 4-bin algorithm
    - » Single broadband K channel
  - Laser monitored fast delay lines

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System visibility tests

- Test on March 14, 2001
- Single broadband K channel, no fringe centering yet
  - Range of visibilities correspond to different points on fringe envelope
- Peak measured V^2 ~ 55%
  - Implies system V^2 of ~75% for given source diameters

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Keck-Keck baseline stability

- Test on March 14
- 9 stars used to solve for Keck-Keck baseline using a priori star positions
- Delay range: +/- 10m (fixed LDL position)
- Delay residuals after solution:
  - ~100 μm rms using ideal pivot model

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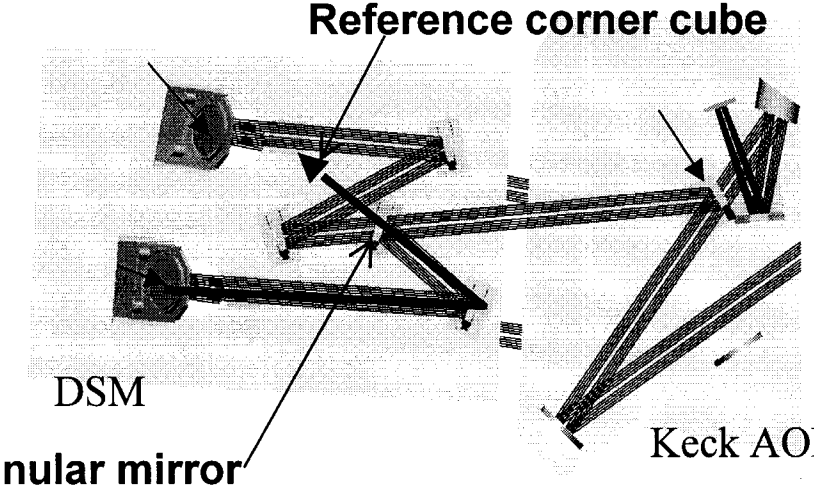
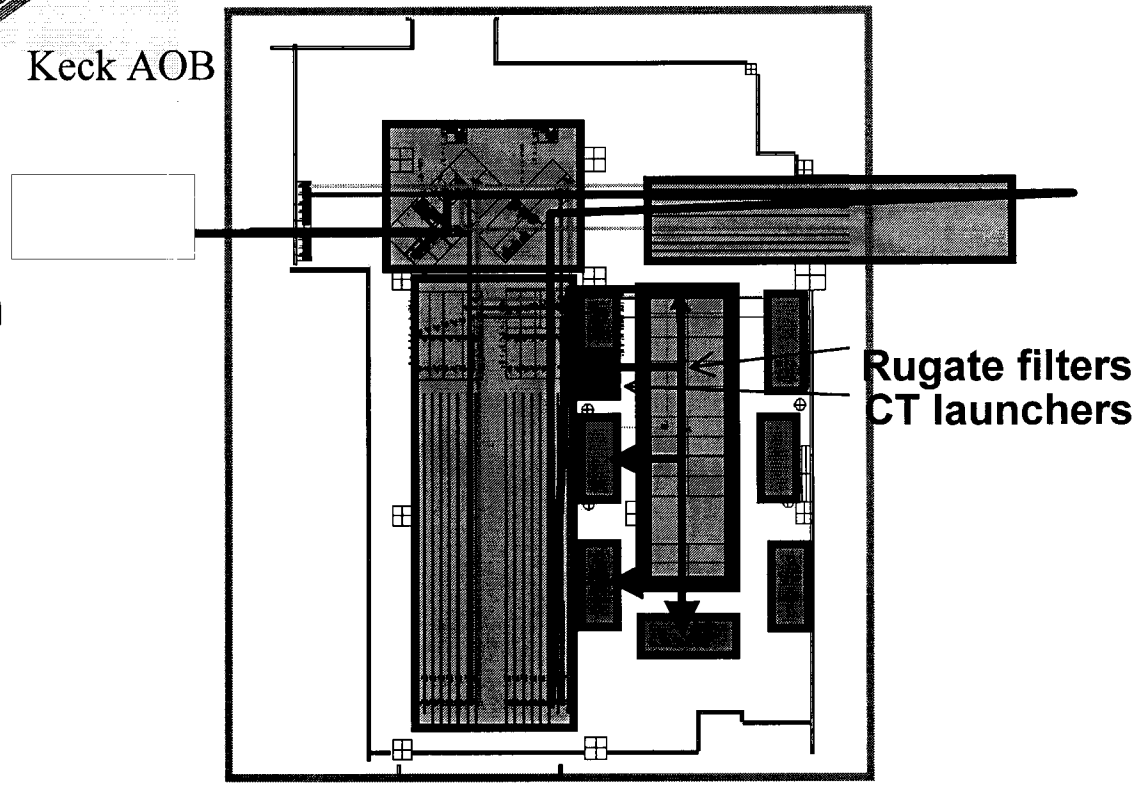
Recent work

- System validation
- V^2 mode improvement
  - Performance, especially improving OPD and tilt stability
  - Functionality
  - Automation
- Mode handoff process
- NASA shared risk science

See: M. Hess, et al. "Strategy for identifying and mitigating facility vibrations at WMKO", 4837-39
M. Hrynevych, et al., "Keck Interferometer: from development phase to facility class instrument,"4844-29

Internal pathlength (CT) metrology





- Adds laser metrology of (almost) entire optical path
- Measured position error combined with local FDL metrology to control FDL position

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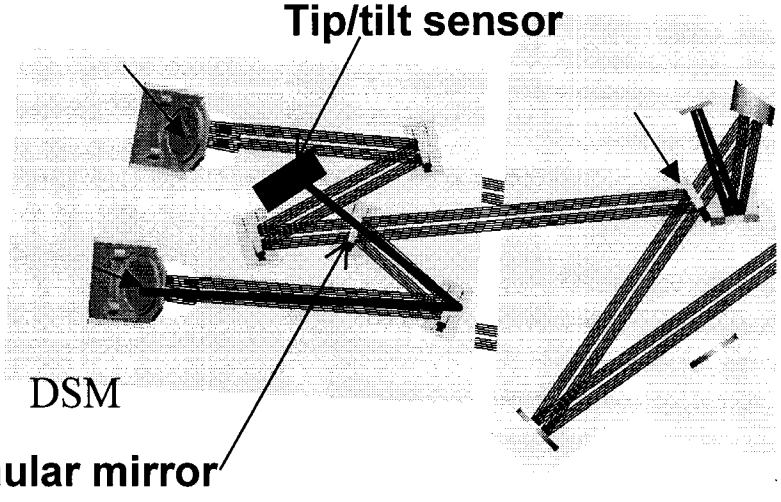
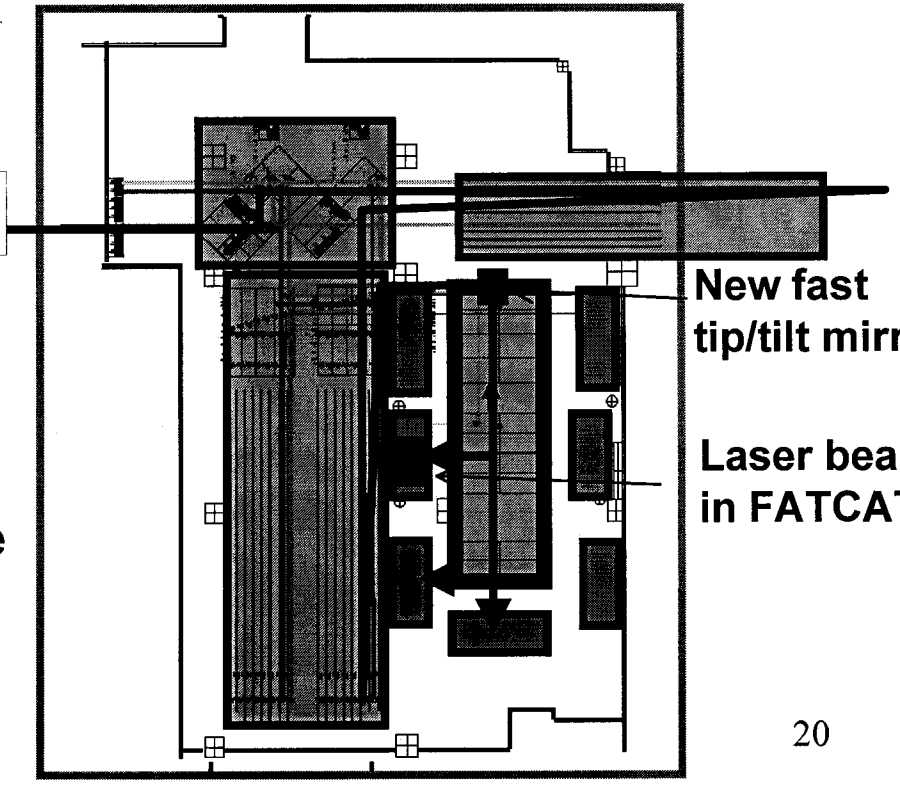
Tip/Tilt metrology



- TTM system
  - Adds sensor at DSM which measures tilt of boresight laser
  - Adds fast tip/tilt mirrors in lab
  - Fast servo control of t/t mirrors
    - » Also incorporates slower mirror control using error measured with starlight angle tracker (KAT)



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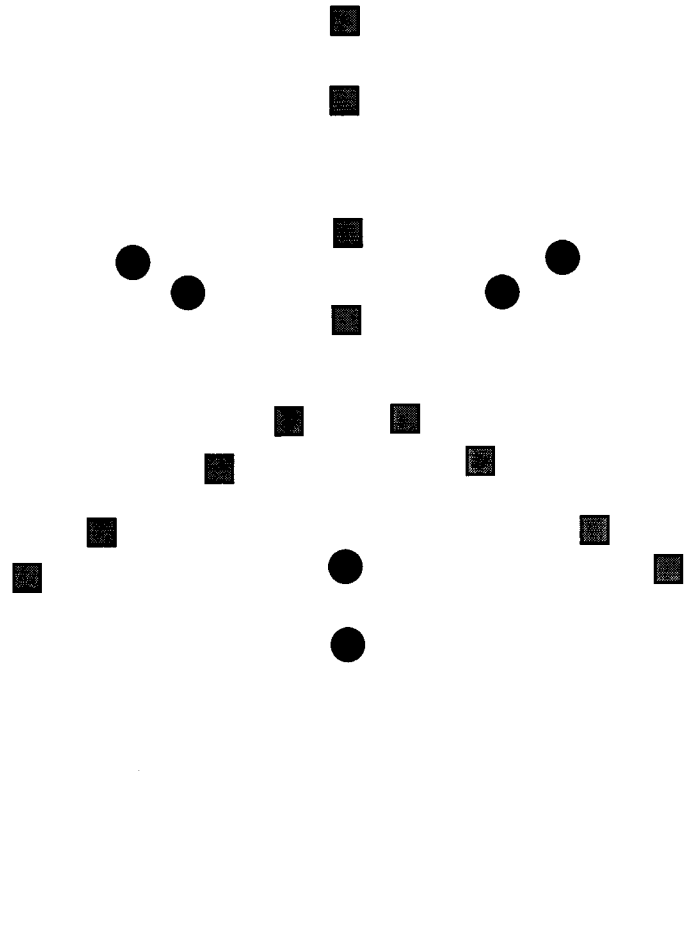
Accelerometer feedforward system

- For each telescope
  - 6 accels installed on primary
  - 3 each on secondary, tertiary
  - 3 on AOB and DSM
- Signals combined to generate feedforward correction to FDL to cancel OPD variation contributed by telescope



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Validation tests

- V^2 mode characterization and validation
- In progress – includes measurement of sources with known parameters (e.g. binaries with well-determined orbits from PTI)

HD120064, April 27, 2002

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Other activities

- Shared-risk teams
  - NRA released by NASA to select teams to participate in shared-risk science with Keck Interferometer
  - 4 teams selected last October
    - » Danchi et al.
    - » Kulkarni et al.
    - » Monnier et al.
    - » Traub et al.
  - Initial shared-risk observations in Jun 2002
- Begin V^2 mode handover process
- Instrument tasks for improved automation and functionality

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Future activities

- Nulling and differential phase modes
  - Summit preparations
  - Continued laboratory development
  - Installation and testing

See:
- E. Serabyn, "Nulling interferometry", 4838-125
- C.D. Koresko et al., "Longitudinal dispersion control for the Keck Interferometer nuller," 4838-127
-C.D. Koresko et al., "Tabletop mid-infrared nulling testbed ...", 4838-132
-Y. Gursel, "Picometer-accuracy laser-metrology gauge for differential phase," 4838-167

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